Reduction of biogenic uranyl phosphate nanoparticles by three metal-reducing bacteria

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The transformations of U in subsurface environments are controlled by a number of bacterially-driven precipitation and redox reactions. We examined the ability of three dissimilatory metal-reducing bacteria (*Anaeromyxobacter dehalogenans* strain K, *Geobacter sulfurreducens* PCA, and *Shewanella putrefaciens* CN32) to reduce U (VI) in three forms: hydrogen uranyl phosphate (HUP) nanoparticles on the cell wall of *Bacillus subtilis* bacteria precipitated by passive cell wall biomineralization; abiotically precipitated HUP; and aqueous uranyl ion. The reduction experiments were conducted at pH=6.8 with presence and absence of bicarbonate and phosphate. X-ray Absorption Fine Structure spectroscopy (XANES and EXAFS) showed varied reduction extent of U (VI) by the three bacteria. The biogenic HUP mineral was consistently more easily reduced than the abiotic HUP under the same experimental conditions. Higher extent of reduction was observed in the presence of bicarbonate. Reduction experiments under conditions that inhibited the HUP dissolution (i.e. high phosphate concentrations) showed smaller extents of U (VI) reduction. These results indicate reduction of the dissolved U (VI) species in the system, as opposed to direct electron transfer to the HUP mineral. EXAFS analysis shows that the reduced U (IV) species are consistent with mono-and bi-dentate phosphate complexation of the U (IV) atoms, as found in the $U^{IV}Ca(PO_4)_2$ mineral ningyoite.

Radioactive element abundances, paleo-heat flows, and the internal evolution of Mars

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Lithospheric strength, crustal and mantle lithosphere composition and orbital measurements of radioactive element abundances can be used together to estimate paleo-heat flows for Mars (e.g. [1]), which help us to constrain the thermal evolution of this planet. In this work we present estimates of paleo-heat flow for several martian regions of different periods and geological context, derived from lithospheric strength and regional radioactive element abundances obtained with the *Mars Odyssey* Gamma Ray Spectrometer. The obtained surface heat flows are in general lower than the equivalent radioactive heat production of Mars in each time, suggesting a limited contribution from secular cooling to the heat flow during the majority of the history of Mars. This is contrary to the predictions from the majority of thermal history models [2], but it would be consistent with an inefficient cycling of volatiles to and from the mantle [3], as might be expected for Mars, which has lacked a plate tectonic cycle.

[1] Ruiz *et al.* (2008) *EPSL* **270**, 1–12. [2] Hauck & Phillips (2002) *JGR* **107**, 5052. [3] Sandu *et al.* (2011) *JGR*, submitted.